CEMENT AND LIME MANUFACTURE

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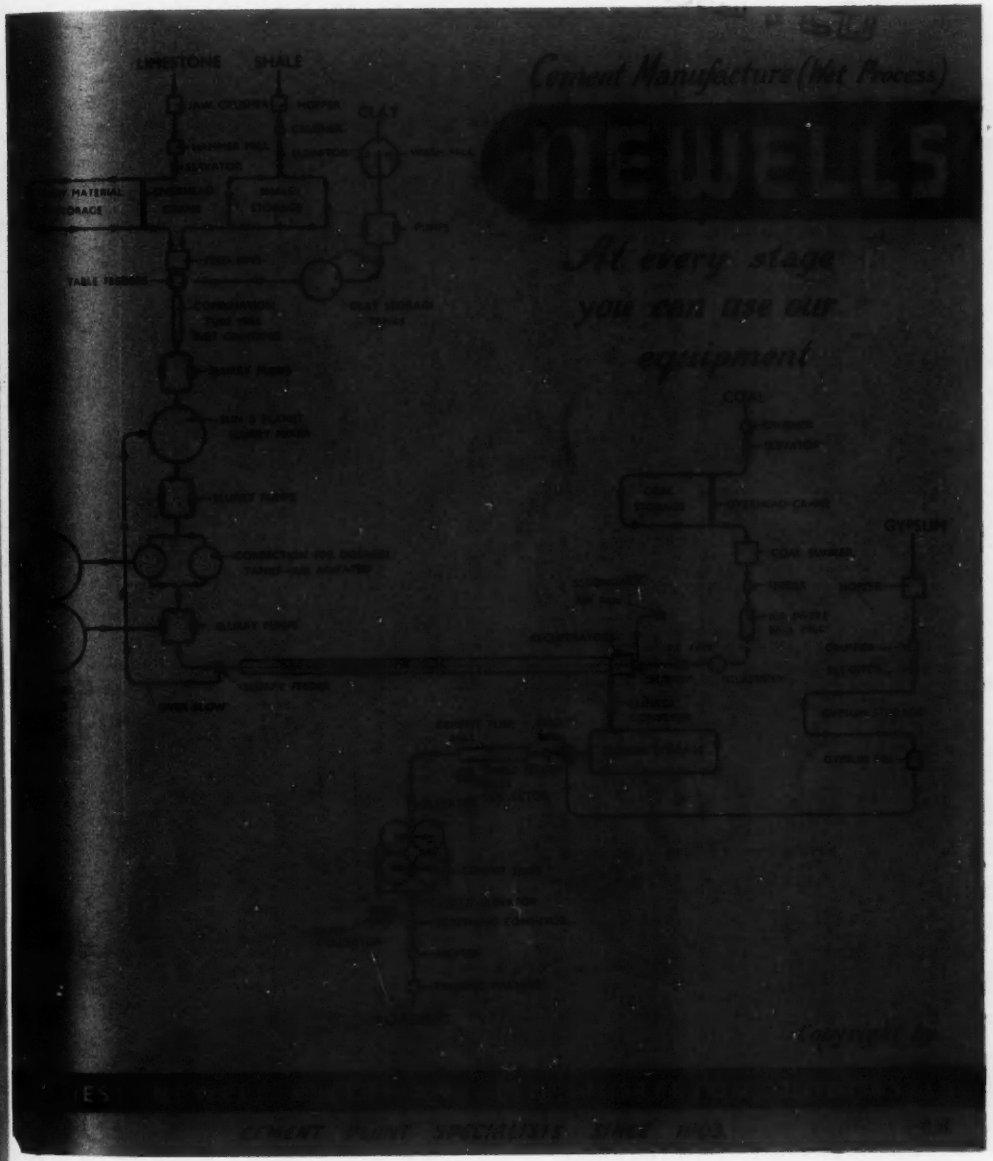

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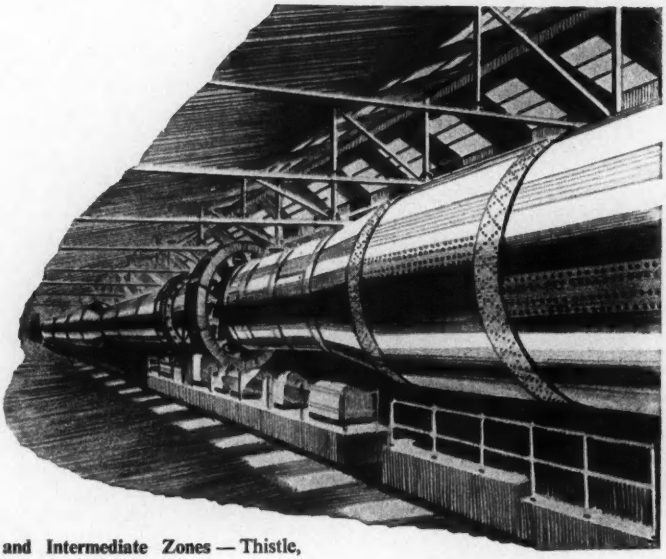

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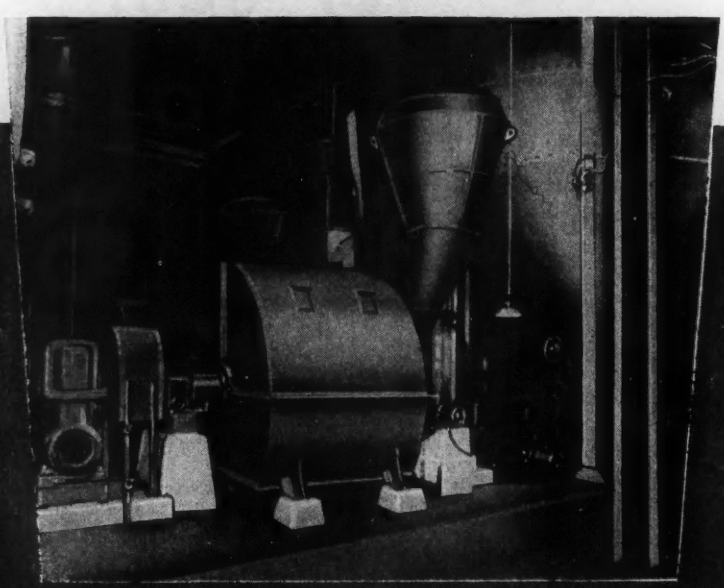

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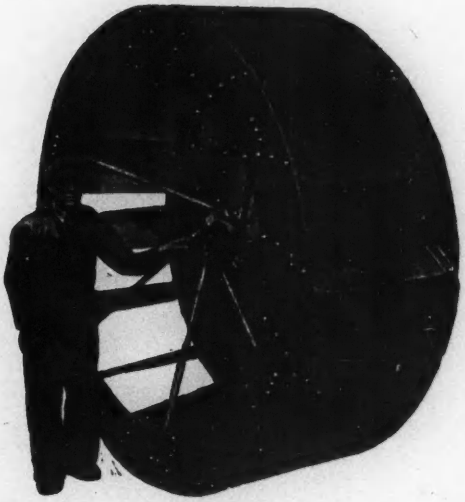

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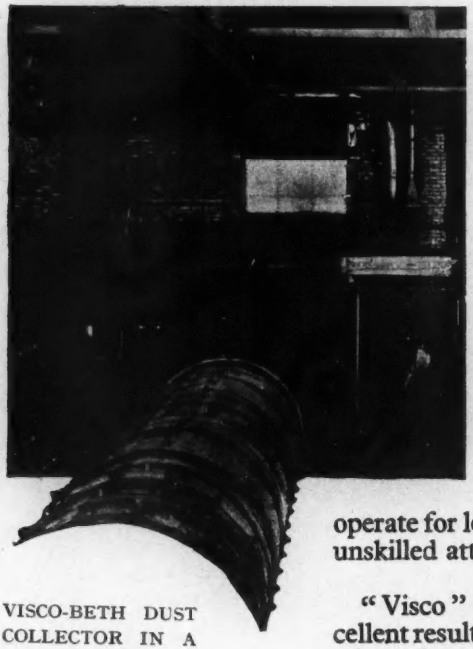

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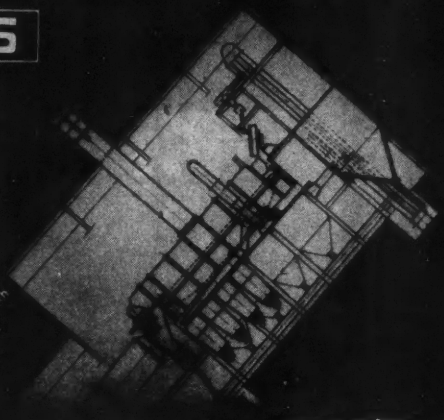

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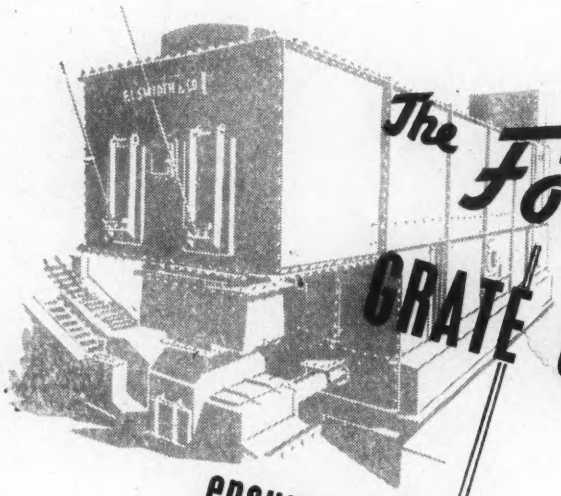

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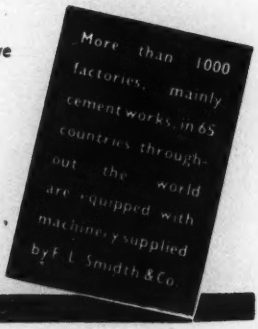
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The Strength of Portland Cement.

AT a meeting of the Structural and Building Engineering Division of the Institution of Civil Engineers, held in London last year, a discussion was held on the desirability or otherwise of having available cements of varying strengths for different classes of work, and particularly a weaker cement at a cheaper price for concrete work in which a lower strength would be satisfactory. The view was also expressed that the cost of concrete could be reduced if cements were of more uniform strength.

MR. F. S. SNOW (a consulting engineer) said that the 28-day strength of cement from different works ranged from 3,000 to 5,000 lb. per square inch. Among the reasons for lack of uniformity in their products were: (1) That some cement works were out of date and so far it had not been possible to obtain building licences or materials to modernise them; the Ministry of Works admitted that, whilst they considered the manufacture of cement vitally important, this was substantially correct. (2) That the quality of coal was in many cases such that it did not permit the manufacture of a cement of high quality; this was corroborated by the Ministry of Fuel and Power. (3) That closer supervision of the manufacture would assist in the production of a more uniform product, and the Ministry of Labour agreed that they were not in a position to supply labour for this purpose. However, the fact that there was one standard price for all cements irrespective of quality was hard to comprehend.

Practically all cements had a strength in excess of British Standards requirements, but if there were greater uniformity in manufacture, with the consequent grading of quality, then if the highest-quality cement were used the sizes of structural members could be correspondingly reduced. It was suggested that where a low-quality concrete was required for such purposes as drain-pipe surrounds, filling behind retaining walls, etc., it should be possible to purchase a

low-grade cement at a reduced price ; by far the greatest quantity of cement used was in this category. Similarly, where concrete had to comply with a British Standard, a structural grade of cement should be obtainable and, where the highest-quality concrete was called for, a high-quality cement should be procurable at a possibly increased price. The cement industry in Great Britain had some of the finest chemists in the world ; its cement was cheaper than in other countries, and to this extent the British were far in advance of any other nation. The work done in the research departments of the cement manufacturers was second to none. However, an explanation was required of why it was necessary to pay 84s. per ton for cement which made concrete with a compressive strength of 3,000 lb. per square inch and the same price for cement which gave a strength of 5,000 lb. per square inch.

DR. F. M. LEA, C.B.E., of the Building Research Station, said that for many years the Building Research Station had tested each batch of cement received for compliance with British Standard No. 12, and also tested concrete cubes made with standard aggregates in accordance with the requirements of codes of practice. About 140 batches of cement had been tested, but as only a limited number of brands had been used the results might not be fully representative of all cements. The tests for the compressive strength of vibrated mortar cubes indicated that about half the ordinary and rapid-hardening Portland cements overlapped in strength. Also there was wide variation in strength at ages up to 28 days, and there was obviously a need for careful consideration of this variation in order to obtain the most efficient and economical use of cement. The wide variations that often occurred in the strength of concrete cubes made on constructional works arose from so many factors that only in favourable cases was it possible to isolate the effect of the cement alone. In the standard tests at the B.R.S., however, cubes were made with a standard aggregate consisting of washed uncrushed river gravel and sand of controlled grading. The proportions (by weight) were 1 : 2 : 4, the water-cement ratio 0·6, and the preparation, storage, and testing followed the recommendations of C.P. 114.

The permissible stresses in concrete were based on the minimum " works strength " of the concrete at 28 days. There was no measure of the minimum strength that might occur, and the specified minimum might be regarded as the value for which there was a probability of, say, only 1 per cent. or less, that lower strengths would occur. This meant that a considerable proportion of concrete used in structures was very much stronger than was necessary simply in order to ensure that no sample fell below a fixed value. Cement was thus wasted, particularly when the variability of strength was high. Variability of strength arose from the cement and from the degree of control exercised in concrete-making. The variability arising from poor control much outweighed that due to the cement, but with good control the latter became an important cause. The coefficient of variation could be reduced to 10 to 12 per cent. with very good control, but a coefficient as high as 27 per cent. could occur with poor control. In order to ensure that not more than one set of cubes in a hundred fell below the specified minimum, the average strength must be much higher if the control were poor.

The coefficient of variation of the 28-day strengths of standard tests at the B.R.S. was 13·5 per cent. for both ordinary and rapid-hardening Portland cement. The lower coefficients for "good" control in practice evidently required a much stricter control on the variability of cement than mere compliance with B.S. No. 12. A sub-division of ordinary and rapid-hardening Portland cements into, say, three grades would be more closely related to the requirements of the user and so enable more economical use to be made of cement.

Since permissible concrete stresses were normally linked with 28-day strengths, they did not in themselves demand any particular strength of a cement at earlier ages. The need for this arose from other causes. Thus, for speed in testing, it was necessary that tests be made at earlier ages and used as an indication of the strength that would be developed later. Again, certain minimum rates of development of strength were required for constructional convenience, and in some types of work, such as prestressed concrete, rapid development of strength was an economic necessity. If three grades of cement were introduced they might be classified as follows: Grade 1, for general building work, such as site concrete, haunching, brickwork, etc.; Grade 2, for structural work in plain or reinforced concrete; Grade 3, for special reinforced concrete work such as shell structures and for prestressed concrete. Grade 1 could be as ordinary cement at present, and the strength of Grades 2 and 3 could be respectively lower and higher than rapid-hardening cement. Grade 3 would presumably only be demanded where high strength at early ages was essential. Grade 2 would allow somewhat leaner mixes to be used to achieve a specified 28-day concrete strength than was practicable

TABLE 1.—PROPOSED STRENGTH GRADINGS.

Cement	Minimum compressive strength of vibrated mortar cubes (lb. per square inch)			
	1 day	3 days	7 days	28 days
Grade 1	—	1,600	2,500	4,000
Grade 2	—	2,500	4,000	5,000
Grade 3	1,600	4,000	5,500	7,000
Present ordinary	—	1,600	2,500	—
Present rapid-hardening	1,600	3,500	—	—

with ordinary cement at present. With these assumptions as a basis, the grades shown in *Table* 1 might be considered. If it were desired to introduce a 1-day strength requirement, this need be applied only to Grade 3. All cements now marketed should satisfy the requirements for Grade 1. All rapid-hardening Portland cements and a high proportion of ordinary Portland cements would satisfy the requirements of Grade 2. More than half the rapid-hardening Portland cements and some of the ordinary Portland cements would satisfy the requirements of Grade 3. Thus it should be possible to have these three grades of cement by selection from present manufacture without developing new and stronger cements. This selection would have the additional effect that the variability of strength

within each grade would be smaller than at present ; greater uniformity might well be as important as an enhanced minimum strength in allowing economy in structural design.

DR. L. J. MURDOCK said that for many purposes, including brick mortar and renderings, no great strength was required, and any cement complying with the minimum requirements of the present British Standards was acceptable. Further, much concrete did not require to have a very high strength, for example plain concrete, oversite concrete for houses, and sub-bases for roads. It followed that a considerable proportion of cement could have a much smaller margin in excess of the existing British Standard requirements than was common with most present-day British cements, provided it could be delivered at a lower price. Such a cement might possess advantages in, say, lower drying shrinkage and slower heat-generation. If several grades of cement were introduced it appeared unlikely that every works would be able to produce all grades, and consumers might have to pay for long and costly hauls if they insisted on a certain grade which was not in production locally. In the United States of America, although specifications existed for a number of grades of cements, it was very difficult to obtain any other than the two common grades unless the requirements were large enough to take the whole output of at least one kiln. Also, ordinary Portland cements did not all harden at the same rate, so that the grading would possibly differ according to the age at which the crushing strength was decided. The grading system appeared likely to become cumbersome if provision were made to allow for such differences.

Strength grading did not provide any guide to the other properties of cements in which differences were found as, for example, sulphate resistance. More attention needed to be given to the influence of the cement on durability, permeability, and other useful properties, and it was undesirable to place too much emphasis on strength.

In view of the disadvantages of a strength-grading system, in that it centred interest on only one property of the cement, whilst it might lead to supply difficulties and an increase in cost, particularly for work not requiring a high strength, it was suggested as an alternative that (1) The present B.S. for ordinary Portland cement be retained as providing a minimum standard, but with crushing-strength requirements included as obligatory instead of optional as at present. If the vibrated-mortar-cube test were not generally acceptable, it would be essential that another test for crushing strength, not affected by human factors, should be included. (2) The cement manufacturers should publish data including information on crushing strength, chemical composition, fineness, soundness, shrinkage, sulphate resistance, and durability of their products.

MR. EDWARD BURKE, M.Sc. (Associated Portland Cement Manufacturers, Ltd.) said that owing to the variations at and between works and in testing the manufacturers would guarantee only to provide cement passing the British Standard. The variation between works arose largely from the different raw materials and coal used. The variation at a particular works was caused largely by the varying ash content of the coal. Uncontrolled changes in the composition of the raw

materials had been almost completely eliminated, but the variation in the coal ash was at present outside the control of the industry. The variation in the coal ash at a works might be, during quite a short period, as much as 20 to 30 per cent., and was commonly 5 to 10 per cent., and a 10 per cent. variation could lead to a 6 per cent. change in the lime-saturation factor which was one of the determining factors in the rate of hardening of cement. Investigations were proceeding into methods of overcoming this difficulty, but the best that could be done at present was to exercise ingenuity in blending so that at the worst the cement did not fall below the standard.

There was a popular misconception that rapid-hardening Portland cements were made at the most modern and efficient works while slow-hardening (so-called low quality) Portland cements came from out-of-date works. This was not so. The determining factors were the nature of the raw materials and the quality of the coal. In some cases, the slower-hardening cements were more expensive to manufacture.

In most cases a choice of several grades of cement would benefit the convenience of construction rather than the ultimate strength of the concrete. There was evidence that, for comparable mixtures made with different grades of cement, the wide differences in early strength disappeared with increasing age so that after, say, one year there was little to choose between the resulting concretes. This was also true of different batches of the same cement whose early variability tended to be reduced in time. Thus, whilst variability undoubtedly existed and the industry was endeavouring to reduce it, it should be recognised as mainly a short-term matter and of critical importance only when high early strength was essential. The evidence so far was that the variation of cement quality in Great Britain was no greater, and probably less, than that abroad.

The addition of a new grade would necessitate the re-classifying of existing ordinary Portland cement as high-grade and the introduction of a new lower grade. If so, who would want the lower grade, bearing in mind that it would not be cheaper than the higher grade ? It should also be remembered that increasing the number of grades of cement meant extra plant and storage capacity or more stoppages in changing over. A greatly increased demand for cement might counterbalance this effect, but the cement industry was now in full production.

It might be argued that cement with high early strength permitted economy in concrete. It was true that a leaner concrete made with rapid-hardening Portland cement might give an early strength equal to or greater than that of a richer mixture made with a slow-hardening cement, but ultimately the concrete made with slow-hardening Portland cement would be much stronger and, being richer, should have much greater durability, that is resistance to frost, chemical attack, and so on.

One reason why cement was made well above the standard, apart from the coal-ash variation, was that there was considerable variation between testing laboratories. To allow for this, and for some degree of aeration between testing at the works and testing of the site sample, the cement must have a strength at all ages at least 30 per cent. above the requirements of the standard.

For many years the tests for the strength of cement had been based on tests of concrete, but only in recent years had this test been developed to a stage where it was likely to be useful for inclusion in a Standard by formulating it so as to give reasonably reproducible results in all properly-equipped laboratories. This test was being considered by a committee of the British Standards Institution.

To sum up, there were practical difficulties in introducing a new grade of cement. A first step would be to find ways of overcoming the present factor of coal quality. The next would be to reduce the variation in testing, because the difference in strength between ordinary Portland cement and rapid-hardening cement was not great enough to make the introduction of another grade reasonably practicable. Variability in strength was, however, essentially a short-term problem. Nevertheless the industry intended to reduce it, and it was felt that production of a single high-quality cement of low variability, instead of two grades as at present suggested, would be a useful and practical contribution to structural economy.

• • • • •

The problem of the varying strength of concrete, made with the same materials in the same proportions, has recently been discussed in connection with the revision of the British Standard Code of Practice for Reinforced Concrete. This code permits a stress of 1000 lb. per square inch in 1 : 2 : 4 concrete with a crushing strength of " works " cubes of 3000 lb. per square inch at 28 days. This factor of safety is generally agreed to be sufficient to allow for patches of inferior workmanship and poor materials. It has been suggested that at the discretion of the engineer the same factor of safety might be used in cases when a structure will not be loaded until more than 28 days after the concrete is placed, when the factor is greater if no account is taken of the greater strength of concrete at later ages. It is known that such concrete made with sound materials increases in strength by about 30 per cent. between the ages of 28 days and three months, when the strength would be about 4000 lb. per square inch and the factor of safety about 4. At one year such concrete would be about 50 per cent. stronger than at 28 days, and the factor of safety about 4½. The requirements of the code are, quite rightly, conservative. The recommended factor of safety of three, however, applies only when a structure is loaded 28 days after the concrete is placed; the longer the interval between placing the concrete and the application of the superimposed load the greater the factor becomes. If a factor of safety of three is satisfactory at 28 days, then this factor should also be satisfactory if the load is not applied until later.

The suggestion that the stresses recommended by the code for structures loaded 28 days after the concrete is placed be increased by an agreed proportion (say, 10 per cent.) if the superimposed load is not applied until three months after casting the concrete, is a useful one which would result in a saving of cement without reducing the factor of safety assumed in the design. Indeed the factor of safety would be still greater because the strength of the concrete would have increased by more than 10 per cent. between 28 days and three months. This difference between the strength assumed for design purposes and the actual

strength would provide a margin for the reduction in the bond strength and shearing strength and other properties that would result from the use of a leaner mixture. It is possible that under construction loads the factor of safety might be reduced, but this could be allowed for in the design ; and in some cases for such temporary loads a reduction in the factor of safety would be acceptable by most engineers. The possibility of construction loads exceeding the design load must be foreseen and allowed for whether the superimposed load be applied at 28 days or three months, and such matters would still be within the control of the engineer. It has also been suggested that, in the case of multiple-story buildings, the working stresses might be higher in the foundations and in the columns of the lower stories, according to the time that will elapse between placing the concrete and applying the full load.

It may be mentioned that some faulty concretes may have satisfactory strengths at early ages, and that only at later dates is the strength of such concretes found to be below that needed. This is one of the difficulties encountered in attempts to assess the later strength of concrete on its strength at early ages, as, for example, the seven-days' strength that is in Belgium multiplied by a factor to arrive at the assumed strength at later ages. Different factors are used in Belgium in the case of different types of cement, but compressive strength tests at early ages will not always detect a concrete which may fail to gain the expected strength at later ages due to defective cement or deleterious aggregates.

The testing of cement and concrete at early ages is often the cause of complaint that a cement is of a poor quality if it has less than the expected compressive strength when the test is made. Provided that the cement is sound, this indicates a confusion of thought between quality and rate of hardening. All Portland cements, including ordinary, rapid-hardening, and slow-hardening " low heat " cements, have about the same strength at the age of one year or so. The differences between them lie in the rate of hardening. A sound cement is not necessarily of poor quality because at the age of seven or twenty-eight days it has a lower compressive strength than another, for eventually the strengths will be about the same. Speed of hardening is an important consideration, but a slow-hardening cement should not be described as of poor quality. The remedy is to use a cement with quicker-hardening properties, but here again it is found that cements of the same description vary in their rates of hardening. This experience is world-wide, and in the present state of knowledge there is no means of ensuring that the properties of cement are absolutely uniform as it is made from day to day. This is true of most products, otherwise we would not see on a building site broken bricks and tiles and other rejected materials which were less strong than the remainder of the same consignment.

The obvious method of reducing the quantity of cement used is to make concrete of higher strength so that the same or a greater load can be carried by a smaller or the same quantity. In recent years improved methods of making and placing concrete have resulted in considerably higher strengths being more often obtained. Even with the most efficient processes now in use, however, the variation of strength is so great that it is necessary to assume that, with a

reasonable margin of safety, the stress that is allowed is an absurdly small proportion of the highest strength achieved or even of the average strength. Although still higher strengths must be aimed at, it seems that at present it is even more important to strive to make concrete of more uniform strength, so that the lowest strengths will be nearer the average.

This problem is the subject of a paper recently presented to the Institution of Civil Engineers by Mr. N. M. Plum, Director of Research of the Danish National Institute of Building Research. In this paper a study is made of the cost of reducing the variability of the compressive strength of concrete, based upon a statistical analysis of the variability of the compressive strengths of cubes from single batches and from different batches. An investigation is made into the cost of the extra care necessary in the selection of materials and the making of concrete so that the variability in strength is reduced and consequently, for the same working stress, concrete of lower average crushing strength may be used. The author estimates that it might cost as much as 3s. 4d. per cubic yard to reduce from 20 per cent. to 15 per cent. the deviation from the average strength. It is also estimated that if the deviation from the average strength were reduced by 10 per cent., and if this more uniform strength permitted concrete with an average strength of 2680 lb. per square inch instead of 4270 lb. per square inch to be used, there would be a saving in cement of 9s. 6d. per cubic yard. It is, however, the author's view that the cost of improved methods that would result in a reduction of more than 5 per cent. in the deviation from the average strength would be more than could be saved by the use of leaner mixtures.

The author states that concrete placed in a Danish airfield varied in compressive strength at seven days from 3000 lb. to over 6000 lb. per square inch during a period of eight months. Also it was found that of three samples taken at the same time, at intervals during the period, the strength varied by nearly 2000 lb. per square inch; in one case the strength of one of the samples was about 4500 lb. per square inch and of the other two more than 6000 lb. per square inch, while in another case two samples had a strength of a little more than 4000 lb. per square inch and the other of more than 6000 lb. per square inch. Seldom was there a difference of less than 700 lb. or 800 lb. per square inch between the strongest and the weakest of three samples taken at the same time. This experience is not unusual.

The paper also gives the results of some tests made in Denmark on the efficiency of concrete mixers. These tests indicated that there was a coefficient of variability within each batch of 4 per cent. to 5 per cent. in the case of positive mixers with a vertical axis and one type of non-tilting mixer, and of 8 per cent. or 9 per cent. in the case of what are described as ordinary non-tilting mixers. These variations may not, of course, be due only to the mechanical action of the machines; for example the variations may have been less if the period of mixing had been longer, or the differences in the test results may have been due to differences in the making and testing of the samples. In considering differences in the results of tests on samples taken from different batches still further possibilities may affect the results, such as differences in proportioning, grading, and water content.

Lack of uniformity of strength is common to all building materials, although in the case of concrete the differences are greater than in many other synthetic materials due to the variations in all the materials of which it is made and to the difficulty (or perhaps the impossibility) of ensuring that all the site processes of measuring, mixing, placing, consolidating, and curing are carried out in the same manner throughout the work. It is not difficult to ensure that no concrete will have less than a required minimum strength. To do so, however, at present necessitates a much higher average strength, and if this is achieved some of the concrete will still have perhaps five or six times the required minimum strength. This is very wasteful, for it is the possible lowest strength that has to be taken into account in deciding the working stress that is permissible. Laboratory work may help, but the problems are essentially practical ones of making cement of uniform strength, using aggregates of uniform strength and shape, grading and proportioning materials and water accurately, and uniformity in transporting, placing, compacting, and curing. A means of testing that would give a more reliable indication of the strength of the concrete in a structure than do the preliminary and works cube or cylinder tests now in use is also necessary. These test-pieces are seldom representative of the concrete in a structure, or related to the shape and size of the member, or the distribution of stresses in the structure.

Cements used in France.

THE different types of cements used in building and civil engineering work and being manufactured in France are described in " Ciments et Bétons," by J. Cléret de Langavant (Paris: Librairie Armand Colin. 1953. Price 250 fr.). Eighteen different cements are mentioned. In this country some of these would be called plasters rather than cements but nevertheless the French Standards Association has issued specifications for eight cements of which the basic constituent is Portland cement and six specifications for materials such as natural cement, masonry cement, and lime. In addition there are high alumina, pozzolanic and expanding cements for which there would appear to be no standard specifications in France.

The object of this book, which is printed in the French language, is to help the reader to choose the most suitable cement for any purpose. This is done in a clear manner by describing in turn the properties and uses of each cement and by tabulating the cements under suitable conditions of use. The introductory chapters deal in an elementary manner with the manufacture and chemistry of cements in general. The part dealing with concrete is confined to two chapters, comprising about one-sixth of the book, of which the first deals largely with a method, due to Bolomey, of determining the best grading of the aggregates and the second describes very briefly the uses of air-entraining agents, colloidal concrete, expanding cements and, somewhat irrelevantly, prestressed concrete.

Blastfurnace Cement Made on a Construction Site.

THE "Trief" process of making Portland blastfurnace cement is being used by Mitchell Engineering, Ltd., in the construction of two dams near Glen Moriston, Scotland. This process, which is a Belgian invention, was used in the construction of a large dam at Bort-les-Orgues, France. The two dams in Scotland will contain more than 300,000 cu. yd. of concrete, and the arrangement of the concrete plant is shown in *Fig.* 1.

The slag is delivered by road from a steelworks at Glasgow to Glen Moriston, where it is tipped into a hopper (on the left of *Fig.* 1) from which it is taken by

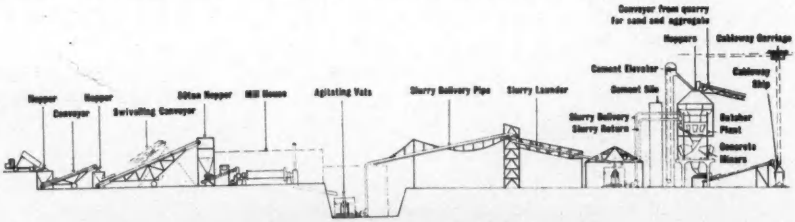


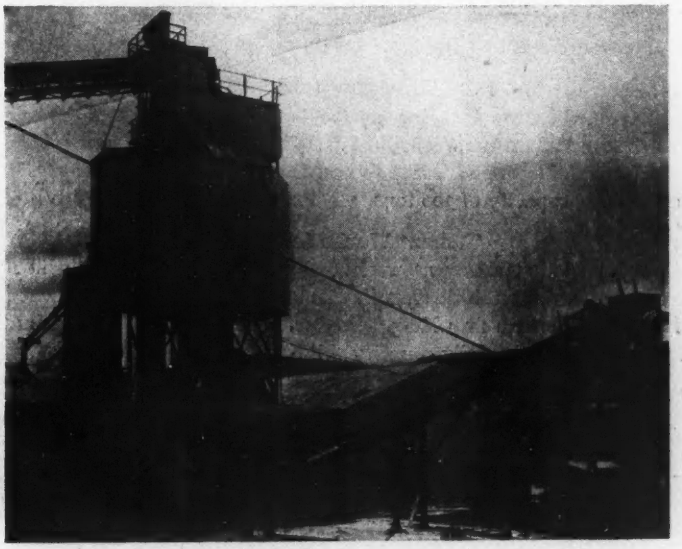
Fig.1.—Arrangement of Plant.

Fig.2.—One of the Mills.

conveyors either to a hopper of 50 tons capacity at the millhouse or to storage. The maximum daily consumption of the mills is about 170 tons.

In the millhouse a rotary-plate feeder delivers the slag to a conveyor-belt, which has a scale on it to weigh the material before it enters the mill. There are two mills, each about 5 ft. diameter by 28 ft. long, and each is driven by a 275-h.p. motor. Each mill can grind to the required fineness 3½ to 3¾ tons of slag an hour. The grinding process is a wet one, and the slurry has a water content of about 30 per cent. When the slurry leaves the mills it passes along sloping launders into tanks, which are provided with stirring gear and compressed air to keep the slurry agitated. The tanks are 14 ft. in diameter by 13 ft. high, and are about 20 ft. lower than the level of the mills.

Due to the nature of the site, the batching plant is some distance from the mills, and the slurry is pumped through steel pipes for a distance of about 200 ft. To keep the pipes clean when the pumps are not working a rubber ball is blown through them. At the end of the pipes the slurry is delivered to tanks near the batching plant, where it is again kept agitated. These tanks, together with the tanks at the mill, provide storage for about 200 tons of slurry. The slurry is pumped to a small tank at the top of the batching plant ; to prevent settlement, a return is taken from the bottom of the upper tank to the lower tank so that the slurry is kept circulating. All the materials required for the concrete (the slurry, Portland cement, sand, and coarse aggregate) are weighed in the required proportions and delivered to the mixer. The concrete is taken by conveyors to hoppers which supply the skips that are carried by cableways to the work.



Concrete Mixing Plant.

Although concrete made with this cement takes longer to harden, it has less heat of hydration than Portland cement and is thus advantageous in large masses of concrete. The process dispenses with the need to grind together the slag and Portland cement clinker as is the case with ordinary Portland blastfurnace cement. If necessary the slurry may be dried and stored.

A result of a typical test showed that a mixture of 1 part of Trief cement to 7 parts of aggregate had the following properties: Density at seven days, 151·9 lb. per cu. ft.; Compressive strength, 1540 lb. per sq. in. at 3 days and 2742 lb. per square inch at seven days. This concrete comprised 1207 lb. of sand,

570 lb. of aggregate from $\frac{3}{16}$ in. to $\frac{3}{4}$ in., 635 lb. of aggregate from $\frac{3}{4}$ in. to $1\frac{1}{2}$ in., 44·5 lb. of aggregate from $1\frac{1}{2}$ in. to $2\frac{1}{4}$ in., 318 lb. of aggregate from $2\frac{1}{4}$ in. to $3\frac{1}{2}$ in., 99 lb. of Portland cement, 348 lb. of slurry, 243 lb. of water (including the water in the slurry), and $5\frac{1}{2}$ lb. of accelerator. All the aggregates, including the sand, were crushed granite.

New Cement Works for Venezuela.

It is reported that a new cement works is to be built in the State of Falcon, that the capacity of the Barquisimeto works is to be increased from 1,000 bags a day to 7,000 bags a day, and that the capacity of the Tachira works is to be increased from 1,000 bags a day to 5,000 bags a day.

New Cement Works in Pakistan.

The Pakistan Industrial Corporation is to build a cement factory at Daudkhel, in the Mianwali district of Punjab.

New Cement Works in India.

It is reported in the U.S. journal "Pit and Quarry" for November, 1953, that the continental firms Brown, Boveri & Cie and Friedrich Krupp have begun the construction of a cement works about 280 miles south of Bombay. The works will have a daily capacity of 300 tons.

Cement Works in Ecuador.

It is reported that a cement works is being built in Ecuador which will be the largest industrial establishment in that country. All the equipment is being supplied by the German firm Miag. Production is expected to begin by the end of the year 1954 and the daily capacity will be 150 tons.

Cement Works for French Equatorial Africa.

A cement works is to be built at Mindeuli, French Equatorial Africa.

New Cement Works in Algeciras.

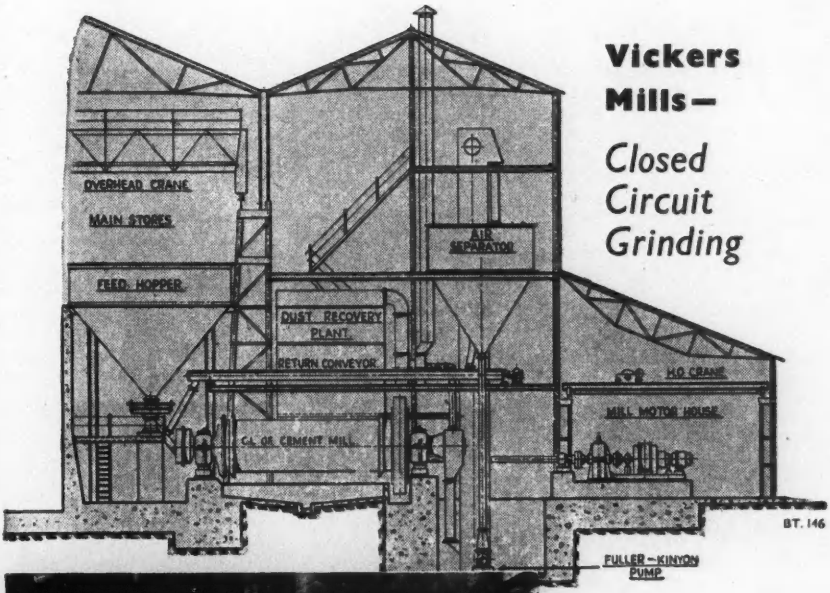
It is reported that a Spanish concern has invited tenders for a new cement works in Algeciras.

Proposed New Cement Works in Jordan.

It is reported that a board of directors comprising seven private members and three members nominated by the Government has been formed to operate a cement factory which is now being built in that country.

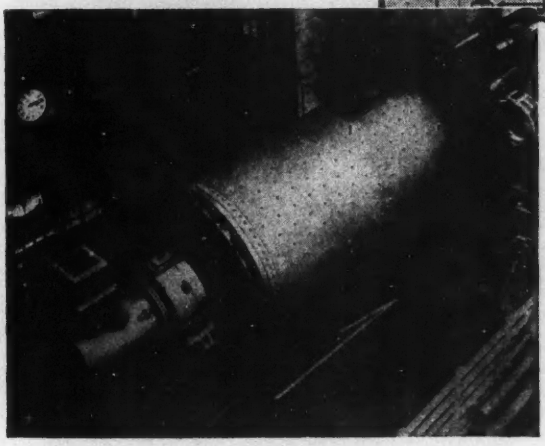
Contracts for Cement Works in Turkey.

Contracts have now been placed for twenty new cement works to be built in Turkey. Seven contracts have been awarded to the firm of Fives (France), six to Krupps, two to Humboldt, two to Polysius, and two to Miag (all of Germany), and one to Ansaldo (Italy). One-fifth of the contract price is to be paid before the installation of the plant, and the remainder, plus interest at the rate of 4 per cent. per annum, during the following five years.



Vickers Mills—

Closed Circuit Grinding



Though a 'closed circuit' makes it easier to control production to a specific fineness, consistent accuracy depends upon the plant being reliable. The trouble-free running synonymous with Vickers mills demonstrates, in fact, that there is no substitute for skill and experience backed by manufacturing capacity.

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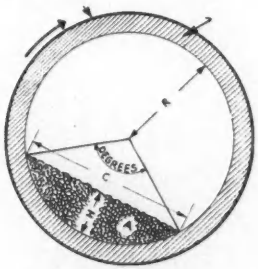
Flow of Material in a Rotary Lime Kiln.

AN attempt to simplify the formula for determining the flow of material in a rotary lime kiln as given in Technical Paper No. 384, " Passage of Solid Particles through Rotary Cylindrical Kilns," issued by the U.S. Bureau of Mines, is made by Mr. Irving Warner in " Rock Products " for May 1953. This formula is

$$t = \frac{1{\cdot}77L\sqrt{\theta}}{pdn}$$

where t is the time in the kiln in minutes, L the length of the kiln in feet, p the slope in degrees, d the diameter inside the lining in feet, n the revolutions per minute,



A = Area of Segment.

and θ is the angle of rest of the material. The following is a summary of the author's comments.

The only value of the formula in this form is to give the length of time for the charge to pass through the kiln ; this is of little practical value. The useful form is to know how far the charge advances per revolution of the kiln.

The angle of repose θ for any pile of limestone fed to the kiln varies slightly ; 36 deg. may be accepted, and $\sqrt{36}=6$. Eliminating time, length of kiln, and revolutions per minute, we get the simple formula $L = \frac{pd}{10{\cdot}6}$. As before, p is the slope in degrees and d the internal diameter. But L is now the travel down the kiln per revolution. L and d are in the same unit such as feet or inches. The formula is in still more usable form if the pitch in degrees is changed to inches per foot. The formula then becomes $L = 0{\cdot}45pd$.

If a kiln has a slope of $\frac{1}{2}$ in. to the foot and an inside diameter of 8 ft., $L = 0{\cdot}45 \times \frac{1}{2} \times 8 = 1{\cdot}8$ ft. travel per revolution. We can now calculate the size of the load in the kiln, that is the dimensions of the segment. If the charge is 720 lb. of stone per revolution of the kiln, and the material weighs 90 lb. per cubic foot, the charge is $720 \div 90 = 8$ cu. ft. per revolution. By the formula, the stone travels 1·8 ft. per revolution, so the area of the segment is $8 \div 1{\cdot}8 = 4{\cdot}4$ sq. ft. Tables giving the dimensions of segments for various areas are given in text books. A line in such a table would be

Degrees	H/R	C/R	A/R^2
89	0·287	1·40	0·277

In *Fig.* 1 degrees is the included angle of the segment, R is the radius of the circle (in this case of the kiln lining), H is the height of the segment or the depth of the load, C is the length of the chord or the surface exposed to the flame, and A is the area of the segment in square feet. The area A of the segment is 4·4 sq. ft. in the 8-ft. kiln where $R = 4$ and $R^2 = 16$. Therefore $A/R^2 = 4{\cdot}4 \div 16 = 0{\cdot}275$. In the table under A/R^2 is 0·275, which is 89 deg. minus. In column H/R the value is 0·287, which may be read as 0·285 since it is slightly less than 89 deg. Therefore $H = 0{\cdot}285 \times 4 = 1{\cdot}14$ ft. = 13·7 in. depth of load. In the same way $C/R = 1{\cdot}40$ and the length of the chord is $1{\cdot}40 \times 4 = 5{\cdot}60$ ft. This is a heavy load, and it can be seen whether it would run over the ring at the feed end. If it is desired to know how much stone can be put in a kiln to give a desired depth, say 12 in., so as not to back over the nose-ring, $H/R = 1$ ft. $\div$ 4 ft. = 0·25. In the table this is 83 deg. minus, so A/R^2, which is 0·228 in the table, can be assumed to be 0·226. $A = 0{\cdot}226 \times 16 = 3{\cdot}62$, the area of the segment. The stone travels 1·8 ft. per revolution, so the volume of stone that can be put in is $3{\cdot}62 \times 1{\cdot}8 = 6{\cdot}5$ cu. ft. per revolution. If the stone weighs 90 lb. per cubic foot the charge per revolution is $6{\cdot}5 \times 90 = 585$ lb.

The load of lime in the calcining zone as seen through the peep-hole in the hood will be less for two reasons. First, there is a densifying action due to abraded material filling the voids. This has been calculated from a known condition as

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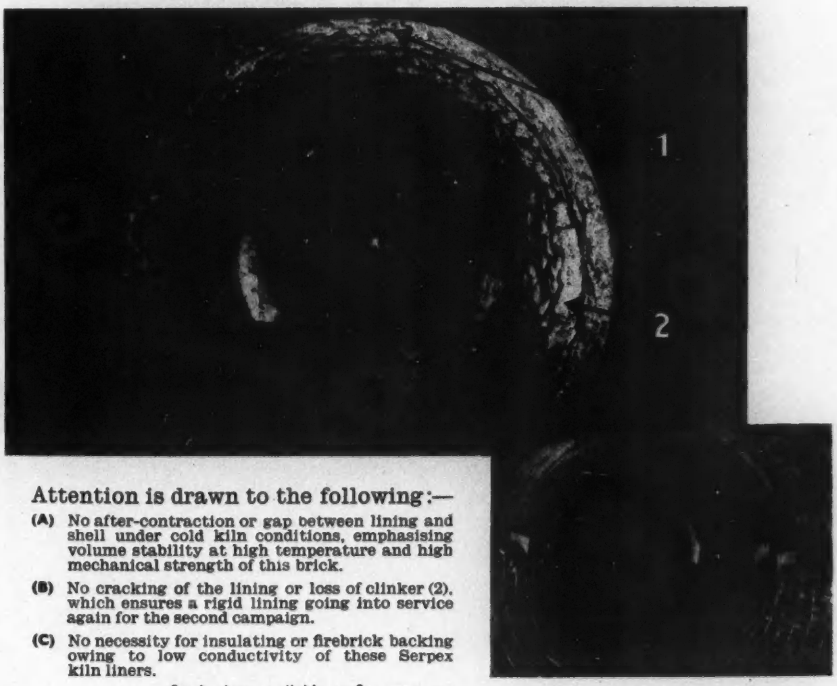

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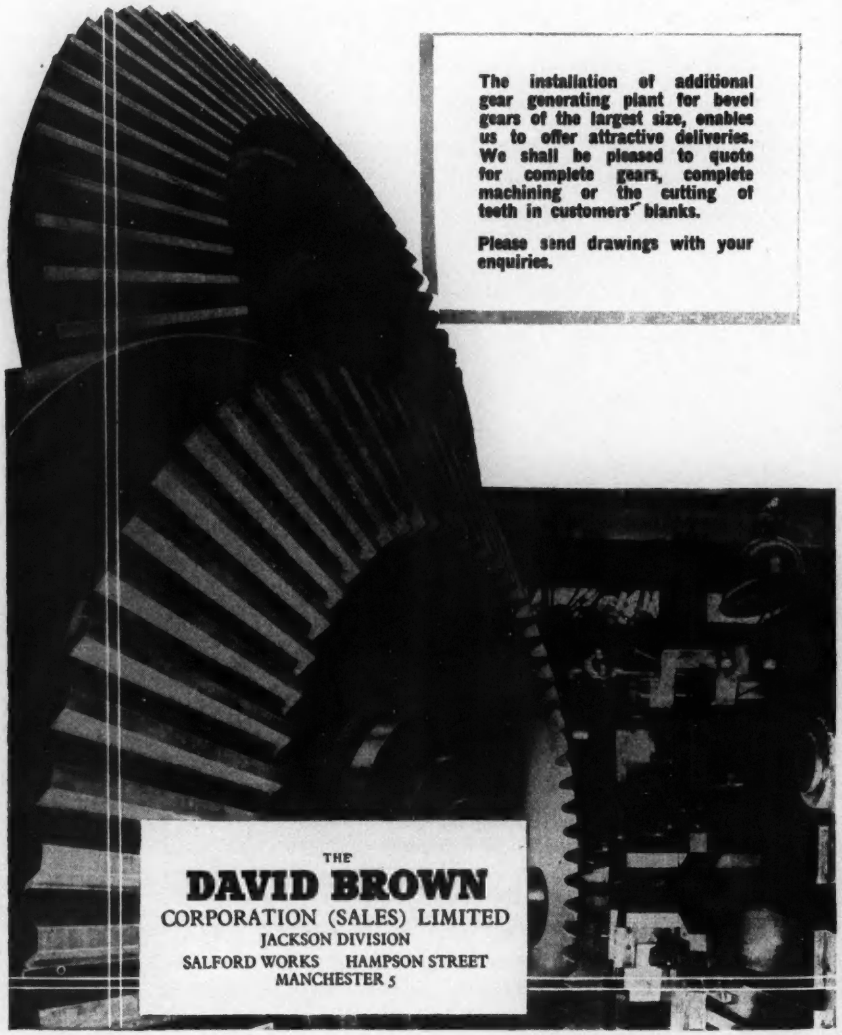

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follows (in lb. per cubic foot). Stone, 90; theoretical weight of lime, 49·5; actual weight of lime, 56; Densification 56/49·5 = 113 per cent. Whereupon the originally calculated area $A = 4{\cdot}4$ sq. ft. becomes $4{\cdot}4 \div 1{\cdot}13 = 3{\cdot}89$ sq. ft., and the depth of load and length of chord are correspondingly less, as calculated from the table. The second error is due to the lesser angle of repose of incandescent lime. This reduces the value of θ, reduces the factor 10·6 in the denominator, and hence increases the travel per kiln revolution. This in turn reduces the area of the segment. It is not at present possible to ascertain the value of θ for hot pebble lime, but the lesser angle exists. If it happens to be 25 deg., then $\sqrt{25} = 5$, and the section is further reduced to five-sixths of its corrected value due to densification.

Determination of Water Content of Hardened Cement.

A REVISED method of determining the non-evaporable water in hardened cement paste is described by Mr. L. E. Copeland (of the U.S. Portland Cement Association) and Mr. J. C. Hayes (of the Zonolite Corporation) in the Bulletin of the American Society for Testing Materials for December 1953. The apparatus used is shown in *Fig.* 1, and the following is an abstract of the paper.

The apparatus consists essentially of a vacuum desiccator connected to the side-arm of a trap by large-bore glass tubing. The small mercury-sealed vacuum stopcock sealed into the side arm is used to break the vacuum when samples are to be removed from the desiccator. The trap is held at — 79 deg. C. by means of dry ice and alcohol. A layer of corrugated cardboard around the trap extends about 8 in. below the side arm. This cardboard is completely covered with rubber tape and serves as an insulator between the trap and the dry ice in the Dewar jar in the region of the dry ice-air boundary. The trap is connected to a mechanical vacuum pump which will keep the pressure in the system below 30μ.

The samples to be analysed are crushed in a mortar or on an anvil. The

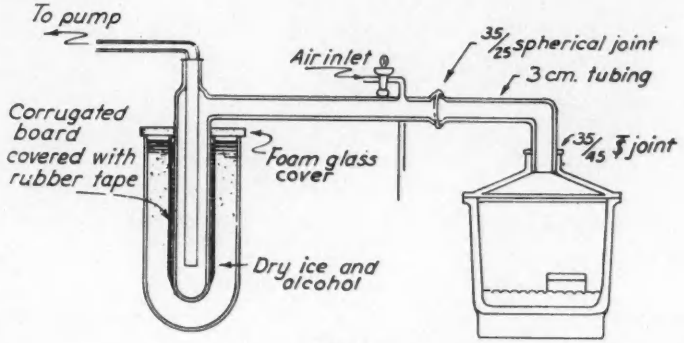

Fig. 1.

material passing a No. 30 and retained on a No. 80 screen is used for the analysis. Five to six grammes of crushed material are spread in a thin layer on the bottom of a weighing dish about 5 cm. in diameter. These operations are performed in a closed cabinet containing air free of CO_2. The dishes are quickly transferred to the desiccator, the apparatus is assembled, and the pump is started, the trap having been previously cooled with a mixture of dry ice and alcohol.

After five to seven days of drying, the samples are removed and weighed. To break the vacuum, dry air free of carbon dioxide is introduced through the stopcock sealed into the side arm of the trap. This stopcock is placed between the desiccator and the trap to prevent the air from passing through the trap into the desiccator and carrying small crystals of ice along with it. The drying is continued until weighings on successive days indicate that the rate of weight loss is no larger than 1 mg. of water per gramme of paste for one day of drying. When the end-point is reached, the weighed sample is ignited at 1050 deg. C. in a platinum crucible for about 30 minutes, then weighed, and replaced in a furnace for a second ignition period of 10 minutes and reweighed. Usually these two ignited weights will check satisfactorily; if they do not, a third ignition is necessary. The weight-loss on ignition is due to the volatilisation of the non-evaporable water and volatile material present in the original cement.

The non-evaporable water is usually expressed in grammes of water per gramme of original cement and is considered to be equal to the increase in ignition loss beyond that of the original cement. It is the difference between the ignition-loss of the paste and the ignition-loss of the original cement, both expressed in grammes of water per gramme of original cement. The ignition loss of the original cement must be determined by a separate experiment.

The following equation (derived by Mr. T. C. Powers) may be used:

$$\frac{w_n}{c} = \frac{W_1}{W_2}(1 - L) - 1$$

where w_n/c is the non-evaporable water content (grammes non-evaporable water per gramme of original cement), W_1 the weight of paste prior to ignition (grammes), W_2 the ignited weight of paste (grammes), and L the ignition-loss of original cement (grammes per gramme of original cement).

The paper discusses the difference between this and other methods, and gives detailed instructions on making the test.

Cement Production in Mexico.

In the year 1953 the production of cement in Mexico amounted to 1,671,567 tons. It is anticipated that the production in the present year will be 2,000,000 tons.

Cement Production in Norway.

The production of cement in Norway in the year 1953 was about 760,000 tons, an increase of 39,000 tons on the previous year.

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